Table 6: Physical Science Content Statements for Grades 4, 8, and 12

GRADE 4	GRADE 8	GRADE 12
Matter		
Properties of Matter: From physical properties common to all objects and substances and physical properties common to solids, liquids and gases (4) to chemical properties, particulate nature of matter, and the Periodic Table of Elements (8) to characteristics of sub-atomic particles and atomic structure (12).		
P4.1: Objects and substances have properties. Weight (mass) and volume are properties that can be measured using appropriate tools.[9] **P4.2:** Objects vary in the extent to which they absorb and reflect light and conduct heat (thermal energy) and electricity. **P4.3:** Matter exists in several different states; the most commonly encountered are solid, liquid, and gas. Each state of matter has unique properties. For instance, gases are easily compressed while solids and liquids are not. The shape of a solid is independent of its container; liquids and gases take the shape of their containers. **P4.4:** Some objects are composed of a single substance; others are composed of more than one substance. **P4.5:** Magnets can repel or attract other magnets. They can also attract certain non-magnetic objects at a distance.	**P8.1:** Properties of solids, liquids, and gases are explained by a model of matter that is composed of tiny particles in motion. **P8.2:** Chemical properties of substances are explained by the arrangement of atoms and molecules. **P8.3**: All substances are composed of one or more of approximately one hundred elements. The Periodic Table organizes the elements into families of elements with similar properties. **P8.4:** Elements are a class of substances composed of a single kind of atom. Compounds are composed of two or more different elements. Each element and compound has physical and chemical properties, such as boiling point, density, color, and conductivity, which are independent of the amount of the sample.[10] **P8.5:** Substances are classified according to their physical and chemical properties. Metals and acids are examples of such classes. Metals are a class of elements that exhibit common physical properties such as conductivity and common chemical properties such as reacting with non-metals to produce salts. Acids are a class of compounds that exhibit common chemical properties including a sour taste, characteristic color changes with litmus and other acid/base indicators, and the tendency to react with bases to produce a salt and water.	**P12.1:** Differences in the physical properties of solids, liquids, and gases are explained by the ways in which the atoms, ions, or molecules of the substances are arranged and the strength of the forces of attraction between the atoms, ions, or molecules. **P12.2:** Electrons, protons, and neutrons are parts of the atom and have measurable properties including mass and, in the case of protons and electrons, charge. The nuclei of atoms are composed of protons and neutrons. A kind of force that is only evident at nuclear distances holds the particles of the nucleus together against the electrical repulsion between the protons. **P12.3:** In the Periodic Table, elements are arranged according to the number of protons (called the atomic number). This organization illustrates commonality and patterns of physical and chemical properties among the elements. **P12.4:** In a neutral atom, the positively charged nucleus is surrounded by the same number of negatively charged electrons. Atoms of an element whose nuclei have different numbers of neutrons are called isotopes.

[9] See textbox on p. 26 for more detail on the distinction between weight and mass.
[10] While this content statement generally holds, there are some compounds that decompose before boiling.

Table 7: Physical Science Content Boundaries for Grades 4, 8, and 12

GRADE 4	GRADE 8	GRADE 12
Properties of Matter: Examples, Observations, and Phenomena		
Common objects, solid and liquid substances found in students' daily lives Exclusions: ▪ Unusual substances and mixtures such as mud that cannot be clearly classified as solid or liquid ▪ Classification of viscous fluids such as glass and obsidian (However, viscous fluids can sometimes be appropriate as examples in assessment tasks. For example, given a description of the physical properties of glass, students could be asked which of the properties are properties of fluids and which are properties of solids.) ▪ Plasma—a fourth state of matter that has unusual physical properties and not often found in students' experience	Common objects, solid and liquid substances found in students' daily lives Some common gases: oxygen, carbon dioxide, air, water vapor, common odors, and volatile liquids Exclusions: ▪ Colloids ▪ Viscous fluids (see grade 4) ▪ Plasma (see grade 4) ▪ Isotopes	Elements in the first two rows of the Periodic Table (Nos. 1-18) Other common elements: iron, gold, silver, mercury, iodine, potassium, titanium, chromium, copper Common compounds of elements cited above Mixtures of elements cited above and compounds, including solutions Isotopes (e.g., of iodine, cobalt, uranium) Exclusions: ▪ Colloids ▪ Viscous fluids (see grade 4) ▪ Plasma (see grade 4)

Table 7: Physical Science Content Boundaries for Grades 4, 8, and 12 (cont.)

GRADE 4	GRADE 8	GRADE 12
Properties of Matter: Instruments, Measurement, and Representations		
Qualitative descriptions using common properties (e.g., solid and liquid, color names, stretchy, springy) Linear measures, using rulers or meter sticks, in cm and m Volume measures using repeated cubes, measuring cups, or graduated cylinders, in mL or L Weight (mass) measures or qualitative comparisons using spring scales or double pan balances in g or kg Simple bar graphs and tables, pictures, or diagrams Exclusions: ▪ Volume measures using cm^3 ▪ Newtons (especially since weight/mass distinction is inappropriate at this level)	Qualitative descriptions of properties of solids, liquids, and gases Measures of mass, volume, and linear measures, accurate to tenths of g, mL, cm^3, cm, using standard measuring instruments and techniques, including triple beam balances and water displacement Calculated measures of density in g/mL or g/cm^3, including relative densities (sinking and floating) Classification of elements as metals or non-metals Drawings of common atoms and molecules (such as H_2O and CO_2) showing how atoms are linked to make molecules (not internal structure of atoms) Graphs and tables Exclusions: ▪ Chemical formulas (except for common molecules such as H_2O and CO_2)	Measures of linear dimensions, mass, volume, density, melting point, and boiling point using standard laboratory instruments Qualitative descriptions of other chemical and physical properties (limited to conductivity of heat and electricity, solubility) Chemical formulas and equations involving elements and compounds listed in the above "Examples, Observations, and Phenomena" category Drawings of atoms and molecules (using Lewis structures or equivalent—note exclusion below of "Lewis structures" as a vocabulary term) Graphs and tables of physical or chemical properties Use of arrows to represent forces of attraction or repulsion among molecules
Properties of Matter: Technical Vocabulary		
Exclusions: ▪ Compressed ▪ Independent ▪ Mass	[No special vocabulary]	Elements and compounds listed in the above "Examples, Observations, and Phenomena" category Exclusions: ▪ The term, "Lewis structures"

Table 7: Physical Science Content Boundaries for Grades 4, 8, and 12 (cont.)

GRADE 4	GRADE 8	GRADE 12
Properties of Matter: Clarification		
Concrete observable properties of matter and liquid, solid, and gas states See textbox on p. 26 for more detail on the distinction between weight and mass. See Appendix F for elaboration of P4.1 and P4.2.	Measurable chemical and physical properties, particulate nature of matter, and the Periodic Table as a logical organization of the elements according to observed periodicity of properties Note connection between this subtopic and content statements P8.6 and P8.7. See textbox on p. 26 for more detail on the distinction between weight and mass.	Key idea: Power of the Periodic Table to enable predictions (e.g., properties, reactivity) See clarification statements under content boundaries for "Changes in Matter." Note connections between this subtopic and content statements P12.6 and P12.23. See textbox on p. 26 for more detail on the distinction between weight and mass. See Appendix F for elaboration of P12.1.

Table 6: Physical Science Content Statements for Grades 4, 8, and 12 (cont.)

GRADE 4	GRADE 8	GRADE 12
Matter		
Changes in Matter: From changes of state (4) to physical and chemical changes and conservation of mass (8) to particulate nature of matter, unique physical characteristics of water, and changes at the atomic and molecular level during chemical changes (12).		
P4.6: One way to change matter from one state to another and back again is by heating and cooling.	**P8.6:** Changes of state are explained by a model of matter composed of tiny particles that are in motion. When substances undergo changes of state, neither atoms nor molecules themselves are changed in structure. Mass is conserved when substances undergo changes of state. **P8.7:** Chemical changes can occur when two substances, elements, or compounds react and produce one or more different substances, whose physical and chemical properties are different from the reacting substances. When substances undergo chemical change, the number and kinds of atoms in the reactants are the same as the number and kinds of atoms in the products. Mass is conserved when substances undergo chemical change. The mass of the reactants is the same as the mass of the products.	**P12.5:** Changes of state require a transfer of energy. Water has a very high specific heat, meaning it can absorb a large amount of energy while producing only small changes in temperature.[11] **P12.6:** An atom's electron configuration, particularly of the outermost electrons, determines how the atom can interact with other atoms. The interactions between atoms that hold them together in molecules or between oppositely charged ions are called chemical bonds. **P12.7:** A large number of important reactions involve the transfer of either electrons (oxidation/reduction reactions) or hydrogen ions (acid/base reactions) between reacting ions, molecules, or atoms. In other chemical reactions, atoms interact with one another by sharing electrons to create a bond. An important example is carbon atoms, which can bond to one another in chains, rings, and branching networks to form, along with other kinds of atoms—hydrogen, oxygen, nitrogen, and sulfur—a variety of structures, including synthetic polymers, oils, and the large molecules essential to life.

[11] See textbox on p. 27 for more detail on the unique properties of water.

Table 7: Physical Science content Boundaries for Grades 4, 8, and 12 (cont.)

GRADE 4	GRADE 8	GRADE 12
Changes in Matter: Examples, Observations, and Phenomena		
Changes of state at the macroscopic level: melting, freezing, evaporation, and condensation Temperature changes associated with physical changes Familiar relationships between changes in matter and heating and cooling	Use of the particulate nature of matter to explain physical changes (changes of state including sublimation, diffusion, thermal expansion, solution) at the molecular/atomic level Chemical changes that illustrate evidence that a change is chemical rather than physical Differences between physical and chemical changes (e.g., physical changes are reversible; chemical changes involve production of a new substance) Qualitative measures of temperature change and thermal energy associated with chemical and physical changes Influences (qualitative only) on the temperature of freezing and boiling, such as pressure or contamination (e.g., by salt) See content statement P8.5 for examples of chemical changes (metals reacting with non-metals and acids reacting with bases).	Classification of chemical changes as oxidation-reduction, acid-base (neutralization), synthesis, or decomposition Photosynthesis included as a synthesis reaction Respiration included as an oxidation-reduction reaction Use of particulate nature of matter to explain chemical changes and to explain the difference between physical and chemical changes Measures of temperature and thermal energy changes associated with physical changes Distinction between physical changes that result in taking energy from the surroundings and those that add energy to the surroundings Phenomena that are used to support a theory of matter composed of small particles in motion including those from "Properties of Matter" and qualitative relationships among temperature, pressure, and volume of gases, Brownian motion, diffusions of a soluble substance in a liquid, and sublimation

Table 7: Physical Science Content Boundaries for Grades 4, 8, and 12 (cont.)

GRADE 4	GRADE 8	GRADE 12
Changes in Matter: Instruments, Measurement, and Representations		
Beakers, graduated cylinders, balances, and thermometers Metric units of weight (mass), volume, and temperature	Chemical formulas for familiar chemical reactions (such as $2H_2 + O_2 \rightarrow 2H_2O$; $C + O_2 \rightarrow CO_2$) Diagrams representing particles and forces among them in solids, liquids and gases Drawings of common atoms and molecules (such as H_2O and CO_2) showing how atoms are linked to make molecules (not internal structure of atoms) Interpretation of chemical symbols and formulas	Symbols and structural diagrams (Lewis structures) for elements and compounds of importance in Life and Earth and Space Sciences such as sugars and Earth materials (minerals) Chemical equations for oxidation-reduction, neutralization, synthesis, and decomposition reactions of importance in Life and Earth and Space Sciences Simple calculations relating temperature change and thermal energy measured in calories
Changes in Matter: Technical Vocabulary		
Exclusions: ▪ Macroscopic	Condensation, evaporation, freezing, melting	Exclusions: ▪ The term, "Lewis structures"

Table 7: Physical Science Content Boundaries for Grades 4, 8, and 12 (cont.)

GRADE 4	GRADE 8	GRADE 12
Changes in Matter: Clarification		
See p. 107, "Biogeochemical Cycles," for more on the crosscutting nature of changes in matter. See Appendix F for elaboration of P4.6.	Key idea: changes of state and conservation of mass are explained by a particulate model of matter See p. 107, "Biogeochemical Cycles," for more on the crosscutting nature of changes in matter. See Appendix F for elaboration of P8.6.	Energy transfers and relationships among interacting particles as a means of understanding chemical reactions On the atomic scale, electrical forces being responsible for holding an individual molecule together as well as for the attraction between neighboring molecules Note connections between this subtopic and content statements P12.2, P12.4, and P12.23. See textbox on p. 27 for more on the unique properties of water. See p. 107, "Biogeochemical Cycles," for more on the crosscutting nature of changes in matter. See Appendix F for elaboration of P12.5. <u>Exclusions</u>: ▪ Details of van der Waals dispersion forces (London forces) and dipole-dipole attractions

Table 6: Physical Science Content Statements for Grades 4, 8, and 12 (cont.)

GRADE 4	GRADE 8	GRADE 12
Energy		
Forms of Energy: From examples of forms of energy (4) to kinetic energy, potential energy, and light energy from the sun (8) to nuclear energy and waves (12).		
P4.7: Heat (thermal energy), electricity, light, and sound are forms of energy.[12] **P4.8:** Heat (thermal energy) results when substances burn, when certain kinds of materials rub against each other, and when electricity flows though wires. Metals are good conductors of heat (thermal energy) and electricity. Increasing the temperature of any substance requires the addition of energy. **P4.9:** Light travels in straight lines. When light strikes substances and objects through which it cannot pass, shadows result. When light travels obliquely from one substance to another (air and water), it changes direction. **P4.10:** Vibrating objects produce sound. The pitch of sound can be varied by changing the rate of vibration.	**P8.8:** Objects and substances in motion have kinetic energy. For example, a moving baseball can break a window; water flowing down a stream moves pebbles and floating objects along with it. **P8.9:** Three forms of potential energy are gravitational, elastic, and chemical. Gravitational potential energy changes in a system as the relative positions of objects are changed. Objects can have elastic potential energy due to their compression, or chemical potential energy due to the nature and arrangement of the atoms. **P8.10:** Energy is transferred from place to place. Light energy from the sun travels through space to Earth (radiation). Thermal energy travels from a flame through the metal of a cooking pan to the water in the pan (conduction). Air warmed by a fireplace moves around a room (convection). Waves—including sound and seismic waves, waves on water, and light waves—have energy and transfer energy when they interact with matter. **P8.11:** A tiny fraction of the light energy from the sun reaches Earth. Light energy from the sun is Earth's primary source of energy, heating Earth surfaces and providing the energy that results in wind, ocean currents, and storms.	**P12.8:** Atoms and molecules that compose matter are in constant motion (translational, rotational, or vibrational). **P12.9:** Energy may be transferred from one object to another during collisions. **P12.10:** Electromagnetic waves are produced by changing the motion of charges or by changing magnetic fields. The energy of electro-magnetic waves is transferred to matter in packets. The energy content of the packets is directly proportional to the frequency of the electromagnetic waves. **P12.11:** Fission and fusion are reactions involving changes in the nuclei of atoms. Fission is the splitting of a large nucleus into smaller nuclei and particles. Fusion involves joining of two relatively light nuclei at extremely high temperature and pressure. Fusion is the process responsible for the energy of the sun and other stars.

[12] See footnote on p. 29 for more detail on the use of the terms "heat" and "thermal energy" in the *Framework* and *Specifications*.

Table 7: Physical Science Content Boundaries for Grades 4, 8, and 12 (cont.)

GRADE 4	GRADE 8	GRADE 12
Forms of Energy: Examples, Observations, and Phenomena		
Observations of heat (thermal), electrical, light, and sound energy through observations of changes in familiar systems, such as: ▪ Addition of heat (thermal) energy: changes of state ▪ Addition of heat (thermal) energy: burning organic substances (wood, wax, sugar, nuts), qualitative relationships between amount of fuel and heat/light produced ▪ Addition of light energy: warming of objects that absorb light ▪ Addition of sound energy: breaking or vibration of a glass ▪ Electricity: heating of wires, lighting of bulb, ringing of bell, powering of small toys and electronic games	Observations of kinetic energy through observations of changes in familiar systems, such as: ▪ Addition of kinetic energy: wind turning a windmill Observations of potential energy through appearance of related form of energy, such as: ▪ Potential energy stored in food: appearance of thermal energy and motion of muscles ▪ Potential energy stored in wax: appearance of heat and light Observations of thermal energy through conduction, convection, radiation, simple examples of absorption	Observations of nuclear energy through observations of changes in systems containing radioactive substances, such as: ▪ Water used to cool down nuclear reactions in nuclear power plants: observable temperature increase in the water ▪ Radioactive isotopes of elements: emission of particles ▪ Thermonuclear reactions: light emission
Forms of Energy: Instruments, Measurement, and Representations		
Primarily verbal descriptions of evidence of energy in familiar systems, that is, if a change is observed, a form of energy is identified as a probable cause of the change Qualitative descriptions of energy	Primarily verbal descriptions of evidence of energy in familiar systems, that is, if a change is observed, a form of energy is identified as a probable cause of the change Qualitative relationships between the mass of combustible materials and the quantity of thermal energy produced. (For example, when candles are used to heat water, the wax "disappears," and the temperature of the water increases. The mass of wax that burns is directly related to the increase in the temperature of the water.)	Primarily verbal descriptions of evidence of energy in familiar systems, that is, if a change is observed, a form of energy is identified as a probable cause of the change Quantitative measurements of wave properties: frequency, amplitude, wavelength, and velocity
Forms of Energy: Technical Vocabulary		
Exclusions: ▪ Thermal energy	[No special vocabulary]	Alpha, beta, and gamma particles

Table 7: Physical Science Content Boundaries for Grades 4, 8, and 12 (cont.)

GRADE 4	GRADE 8	GRADE 12
Forms of Energy: Clarification		
See footnote on p. 29 for use of the terms "heat" and "thermal energy." Refer to boundaries for "Energy Transfer and Conservation" for appropriate related item content. See pp. 105-106, "Energy Sources and Transfer" and "Uses, Transformations, and Conservation of Energy," for more on the crosscutting nature of energy. See Appendix F for elaboration of P4.8.	See footnote on p. 29 for use of the terms "heat" and "thermal energy." Refer to boundaries for "Energy Transfer and Conservation" for appropriate related item content. See pp. 105-106, "Energy Sources and Transfer" and "Uses, Transformations, and Conservation of Energy," for more on the crosscutting nature of energy. See Appendix F for elaboration of P8.8, P8.9, and P8.10.	See footnote on p. 29 for use of the terms "heat" and "thermal energy." Refer to boundaries for "Energy Transfer and Conservation" for appropriate related item content. See pp. 105-106, "Energy Sources and Transfer" and "Uses, Transformations, and Conservation of Energy," for more on the crosscutting nature of energy. See Appendix F for elaboration of P12.8.

Table 6: Physical Science Content Statements for Grades 4, 8, and 12 (cont.)

GRADE 4	GRADE 8	GRADE 12
Energy		
Energy Transfer and Conservation: From electrical circuits (4) to energy transfer and conservation of energy (8) to translational, rotational, and vibrational energy of atoms and molecules, and chemical and nuclear reactions (12).		
P4.11: Electricity flowing through an electrical circuit produces magnetic effects in the wires. In an electrical circuit containing a battery, a bulb, and a bell, energy from the battery is transferred to the bulb and the bell, which in turn transfer the energy to their surroundings as light, sound, and heat (thermal energy).	**P8.12:** When energy is transferred from one system to another, the quantity of energy before transfer equals the quantity of energy after transfer. For example, as an object falls, its potential energy decreases as its speed, and consequently, its kinetic energy increases. While an object is falling, some of the object's kinetic energy is transferred to the medium through which it falls, setting the medium into motion and heating it. **P8.13:** Nuclear reactions take place in the sun. In plants, light from the sun is transferred to oxygen and carbon compounds, which, in combination, have chemical potential energy (photosynthesis).	**P12.12:** Heating increases the translational, rotational, and vibrational energy of the atoms composing elements and the molecules or ions composing compounds. As the translational energy of the atoms, molecules, or ions increases, the temperature of the matter increases. Heating a sample of a crystalline solid increases the vibrational energy of the atoms, molecules, or ions. When the vibrational energy becomes great enough, the crystalline structure breaks down and the solid melts. **P12.13:** The potential energy of an object on Earth's surface is increased when the object's position is changed from one closer to Earth's surface to one farther from Earth's surface. **P12.14:** Chemical reactions either release energy to the environment (exothermic) or absorb energy from the environment (endothermic). **P12.15:** Nuclear reactions—fission and fusion—convert very small amounts of matter into appreciable amounts of energy. **P12.16:** Total energy is conserved in a closed system.

Table 7: Physical Science Content Boundaries for Grades 4, 8, and 12 (cont.)

GRADE 4	GRADE 8	GRADE 12
Energy Transfer and Conservation: Examples, Observations, and Phenomena		
Electrical circuits: transfer of energy from a battery to light, sound, motion (in wires, light bulbs, buzzers, bells, fans); qualitative relationships between batteries and light bulbs	Falling objects: transfer of gravitational potential energy to kinetic energy and thermal energy produced by friction Transfer of energy from a person lifting an object to gravitational potential energy Power plants: transfer of gravitational potential energy (water power) to mechanical energy to electrical energy; transfer of chemical energy from burning coal or natural gas to mechanical and to electrical energy Plants: transfer of light energy to chemical energy	Calculations of the temperature of a mixture of two liquids of different temperatures and volumes Distinction between chemical changes that either release energy to the surroundings or cause energy to flow from the surroundings into the system

Table 7: Physical Science Content Boundaries for Grades 4, 8, and 12 (cont.)

GRADE 4	GRADE 8	GRADE 12
Energy Transfer and Conservation: Instruments, Measurement, and Representations		
Drawing of a simple electrical circuit containing a battery, bulb and switch (with electrical symbols for wires, bulb, and battery)	Representations of systems involving energy transfer and conservation (e.g., basketball thrown up in the air and falling down to the ground, power plant burning coal for electrical energy)	Calorie as a measure of thermal energy and stored chemical energy Joule as a unit of energy Graphical representation of changes of state as water is heated at a constant rate Use of energy transfer and conservation to explain graphical representations of phase change as thermal energy is added to a system at a constant rate Mathematical reasoning and representations: ▪ Calorimetry: Calculation of changes in temperatures of objects in closed systems ▪ Qualitative comparisons of changes in potential energy with corresponding changes in kinetic energy ▪ Calculations of gravitational potential energy (GPE) of an object very close to Earth's surface and the change in GPE when the distance of the object from Earth's surface is increased (GPE=mgh) ▪ Calculations of kinetic energy and speed of a falling object very close to Earth's surface as the object's GPE decreases ($mg\Delta h+\Delta \frac{1}{2} mv^2=0$)
Energy Transfer and Conservation: Technical Vocabulary		
[No special vocabulary]	[No special vocabulary]	Calorie, joule, exothermic, endothermic

Table 7: Physical Science Content Boundaries for Grades 4, 8, and 12 (cont.)

GRADE 4	GRADE 8	GRADE 12
Energy Transfer and Conservation: Clarification		
Key idea: As one form of energy "disappears" from a system, other forms of energy "appear." Although not explicitly stated, knowing that a closed electrical circuit is necessary for the transfer of energy is implied by content statement P4.11. Refer to boundaries for "Forms of Energy" for appropriate related item content. See pp. 105-106, "Energy Sources and Transfer" and "Uses, Transformations, and Conservation of Energy," for more on the crosscutting nature of energy.	Key idea: As the quantity of one form of energy in a system decreases, the quantity of other forms of energy increases. Note connections between this subtopic and content statements L8.4, E8.11. Refer to boundaries for "Forms of Energy" for appropriate related item content. See pp. 105-106, "Energy Sources and Transfer" and "Uses, Transformations, and Conservation of Energy," for more on the crosscutting nature of energy.	Key idea: Kinetic molecular theory of matter is based on observations, phenomena, and measurements of the type listed above. Kinetic molecular theory of matter accounts for conservation of energy. Note connections between this subtopic and content statements L12.4, L12.5, L12.6, E12.9, E12.12. Refer to boundaries for "Forms of Energy" for related item content. See pp. 105-106, "Energy Sources and Transfer" and "Uses, Transformations, and Conservation of Energy," for more on the crosscutting nature of energy. See Appendix F for elaboration of P12.12 and P12.16.

Table 6: Physical Science Content Statements for Grades 4, 8, and 12 (cont.)

GRADE 4	GRADE 8	GRADE 12
Motion		
Motion at the Macroscopic Level: From descriptions of position and motion (4) to speed as a quantitative description of motion and graphical representations of speed (8) to velocity and acceleration as quantitative descriptions of motion and the representation of linear velocity and acceleration in tables and graphs (12).		
P4.12: An object's position can be described by locating the object relative to other objects or a background. The description of an object's motion from one observer's view may be different from that reported from a different observer's view. **P4.13:** An object is in motion when its position is changing. The speed of an object is defined by how far it travels divided by the amount of time it took to travel that far.	**P8.14:** An object's motion can be described by its speed and the direction in which it is moving. An object's position can be measured and graphed as a function of time. An object's speed can be measured and graphed as a function of time.	**P12.17:** The motion of an object can be described by its position and velocity as functions of time and by its average speed and average acceleration during intervals of time. **P12.18:** Objects undergo different kinds of motion—translational, rotational, and vibrational.

Table 7: Physical Science Content Boundaries for Grades 4, 8, and 12 (cont.)

GRADE 4	GRADE 8	GRADE 12
Motion at the Macroscopic Level: Examples, Observations, and Phenomena		
Comparisons of speed by comparing distances traveled in equal times or times to travel equal distances Position relative to reference object (e.g., positions of balls on horizontal surfaces)	Quantitative comparisons of speeds in different parts of a journey (e.g., to/from inclined surfaces, along horizontal surfaces) Descriptions of the motion of one object relative to another where both are moving along a straight line Change in speed or direction for particular intervals of time	Quantitative comparisons of average speeds and average accelerations in different parts of a journey and/or for different objects Curvilinear paths: circular, parabolic, elliptical, or simply "around a corner" Translational motion of objects or objects moving from place to place (e.g., falling stone); rotational motion of objects or objects turning about an axis (e.g., carousel); vibrational motion of objects or objects moving rapidly back and forth in place (e.g., vibrating guitar string) <u>Exclusions</u>: ▪ Independence of horizontal and vertical motion for projectiles

Table 7: Physical Science Content Boundaries for Grades 4, 8, and 12 (cont.)

GRADE 4	GRADE 8	GRADE 12
Motion at the Macroscopic Level: Instruments, Measurement, and Representations		
Time (at an instant) as read on a clock Time (interval) found by subtracting the first clock-reading from the final clock-reading Measures of time: hours, minutes, seconds Position and distance scales Measuring distance with a ruler, meter stick Measures of distance: cm, m, km Pictures, drawings, or diagrams of positions of objects at different times relative to reference objects or distance scales Pictures, diagrams, or drawings of objects on horizontal surfaces Cardinal points (north, south, east, west) on a compass as reference points for motion in a single plane	Reading speedometers "Freeze-frame" pictures with distance and time scales Tables and graphs of position versus time (clock-readings) and of speed versus time (clock-readings) Pictures, diagrams, or drawings of objects on horizontal surfaces, inclined surfaces Measures of time: hours, minutes, seconds Measures of distance: cm, m, km	"Freeze-frame" pictures with distance and time scales Tables and graphs of position versus time and of speed versus time (same key ideas as at grade 8 but with more complex motions such as speeds that change moment by moment or several different intervals of different constant speeds) Use of vectors to describe and interpret the motion of an object moving along a curvilinear path Pictures of projectiles Calculations of average speeds and average accelerations for different parts of a journey Quantitative comparisons of rates of translation, rotation, and vibration Measures of time: hours, minutes, seconds Measures of distance: cm, m, km
Motion at the Macroscopic Level: Technical Vocabulary		
Distance (from one position on a reference scale to another) <u>Exclusions</u>: ▪ Velocity ▪ Reference object	<u>Exclusions</u>: ▪ Velocity	Average velocity as "a vector including magnitude and direction"

Table 7: Physical Science Content Boundaries for Grades 4, 8, and 12 (cont.)

GRADE 4	GRADE 8	GRADE 12
Motion at the Macroscopic Level: Clarification		
Description of position and motion of objects Relationships between objects and changes in point of view See Appendix F for elaboration of P4.12 and P4.13.	See Appendix F for elaboration of P8.14.	Velocity and acceleration as means of describing the motion of objects Translational motion of objects (difficult to describe because descriptions depend on observer's position and reference frame used) See Appendix F for elaboration of P12.18.

Table 6: Physical Science Content Statements for Grades 4, 8, and 12 (cont.)

GRADE 4	GRADE 8	GRADE 12
Motion		
Forces Affecting Motion: From the association of changes in motion with forces and the association of objects falling toward Earth with gravitational force (4) to qualitative descriptions of magnitude and direction as characteristics of forces, addition of forces, contact forces, forces that act at a distance, and net force on an object and its relationship to the object's motion (8) to quantitative descriptions of universal gravitational and electric forces, and relationships among force, mass, and acceleration (12).		
P4.14: The motion of objects can be changed by pushing or pulling. The size of the change is related to the size of the force (push or pull) and the weight (mass) of the object on which the force is exerted. When an object does not move in response to a push or a pull, it is because another push or pull (friction) is being applied by the environment. **P4.15:** Earth pulls down on all objects with a force called gravity. With a few exceptions (helium filled balloons), objects fall to the ground no matter where the object is on Earth.	**P8.15:** Some forces between objects act when the objects are in direct contact or when they are not touching. Magnetic, electrical, and gravitational forces can act at a distance. **P8.16:** Forces have magnitude and direction. Forces can be added. The net force on an object is the sum of all the forces acting on the object. A non-zero net force on an object changes the object's motion; that is, the object's speed and/or direction of motion changes. A net force of zero on an object does not change the object's motion; that is, the object remains at rest or continues to move at a constant speed in a straight line.	**P12.19:** The motion of an object changes only when a net force is applied. **P12.20:** The magnitude of acceleration of an object depends directly on the strength of the net force and inversely on the mass of the object. This relationship ($a=F_{net}/m$) is independent of the nature of the force. **P12.21:** Whenever one object exerts force on another, a force equal in magnitude and opposite in direction is exerted by the second object back on the first object. In closed systems, momentum is the quantity of motion that is conserved. Conservation of momentum can be used to help validate the relationship $a=F_{net}/m$. **P12.22:** Gravitation is a universal attractive force that each mass exerts on any other mass. The strength of the gravitational force between two masses is proportional to the masses and inversely proportional to the square of the distance between them. **P12.23:** Electric force is a universal force that exists between any two charged objects. Opposite charges attract while like charges repel. The strength of the electric force is proportional to the magnitudes of the charges and inversely proportional to the square of the distance between them. Between any two charged particles, the electric force is vastly greater than the gravitational force.

Table 7: Physical Science Content Boundaries for Grades 4, 8, and 12 (cont.)

GRADE 4	GRADE 8	GRADE 12
Forces Affecting Motion: Examples, Observations, and Phenomena		
Objects (e.g., toys) moving across horizontal surfaces If no force keeps them moving, objects slowing down at rates depending on the kinds of surface (friction) Dropped objects falling to the ground Exclusions: ▪ Passive forces (e.g., support force by a table holding up an object)	Low friction surfaces such as air hockey pucks on air, block of ice on smooth table surface, low friction wheeled cart Surfaces showing the effects of friction on objects moving across them (e.g., toy car on carpet)	Two different masses (different densities but equal volumes) falling from equal heights in approximately equal times (ignoring air resistance) Some objects falling more slowly than others when they have substantial air resistance (e.g., parachute) The ability of a charged rod to lift up a tiny piece of paper, demonstrating that between two charged particles, the electric force is larger than Earth's gravitational force Exclusions: ▪ Quantitative comparisons of electric and gravitational forces

Table 7: Physical Science Content Boundaries for Grades 4, 8, and 12 (cont.)

GRADE 4	GRADE 8	GRADE 12
Forces Affecting Motion: Instruments, Measurement, and Representations		
Measuring push or pull by the relative stretch or compression of an object (e.g., a spring or rubber ring) Equal arm balances used to compare masses	Spring scales to pull objects across different surfaces Force diagrams with arrows to represent the relative magnitude and direction of forces acting on an object of interest (limited to forces acting in a straight line)	Force diagrams on each of two interacting objects; force diagrams with relative magnitudes can be used to compare the forces acting on each object of the pair Use of force diagrams and equations to show qualitatively how two objects of different densities can fall in approximately equal times, if air resistance is not a major factor, and explanations of how major air resistance on an object affects the force diagram and resulting motion of the object $a=F_{net}/m$ to predict or compare accelerations or masses of objects, or the net force acting on objects Conservation of momentum (where momentum=mv) used to predict relative motions or relative masses of two interacting objects along a straight line Relationship of distance to gravitational force: doubling (or tripling) the distance between two masses reduces the magnitude of the gravitational force to one quarter (or one ninth). Relationship of distance to electrical force: doubling (or tripling) the distance between two charges reduces the magnitude of the electrical force to one quarter (or one ninth). Exclusions: ▪ Momentum in two dimensions
Forces Affecting Motion: Technical Vocabulary		
Weight (mass) as measure of heaviness Exclusions: ▪ Friction	Attract, repel (as related to forces)	[No special vocabulary]

Table 7: Physical Science Content Boundaries for Grades 4, 8, and 12 (cont.)

GRADE 4	GRADE 8	GRADE 12
Forces Affecting Motion: Clarification		
More force applied to one movable object will make it move (speed up) faster. With the same force applied to two objects, the heavier one will move (speed up) more slowly. To get a heavier object and a lighter object to move at the same speed, the heavier object requires a bigger push/pull.	Resolution of forces on an object should be confined to motion in a straight line. This subtopic includes a qualitative understanding of Newton's first two laws of motion applied to an object.	Resolution of forces should be confined to horizontal, vertical, or inclines of 30 or 45 degrees. Resolution of orthogonal forces should result in a vector at roughly 30, 60 or 45 degrees relative to one of the "first" vectors. This subtopic includes all three of Newton's Laws of Motion applied to two interacting objects. For all of the mathematical relationships/representations described in this subtopic (see "Instruments, Measurement, and Representations" on previous page), students having a qualitative or semi-quantitative understanding (e.g., mathematical relationships such as proportionality) is more important than calculating particular quantities. See clarification statements under content boundaries for "Changes in Matter." Note connections between this subtopic and content statements P12.2, P12.4, P12.6. See Appendix F for elaboration of P12.19.